



Does cigarette smoking relieve stress? Evidence from the event-related potential (ERP)



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ARTICLE INFO

Article history:

Received 29 June 2015

Received in revised form 10 October 2015

Accepted 19 October 2015

Available online 20 October 2015

Keywords:

Cigarette smoking

Late positive potential

Event-related potentials

Arousal

Stress

ABSTRACT

Previous studies have reported a paradox that cigarette smoking reduces stress psychologically; however, it increases the arousal level physiologically. To examine this issue, our study aimed to investigate whether cigarette smoking relieves stress by measuring the late positive potential (LPP), a component of the event-related potential (ERP). In Experiment 1, participants first watched emotionally neutral images; second, they received a break; and finally, they watched emotionally neutral images again. In the break, they smoked a cigarette (smoking condition) or simply rested without smoking (non-smoking condition). The procedure of Experiment 2 was the same as that of Experiment 1, except that the participants watched unpleasant images as stress stimuli before the break. In Experiment 1, the LPP decreased from before to after the break in the smoking condition, but not in the non-smoking condition, suggesting that smoking cigarettes in the neutral state reduces the arousal level. In Experiment 2, the LPP for 400–600 ms decreased from before to after the break, both in the smoking and non-smoking conditions; however, the LPP for 200–400 ms decreased from before to after the break only in the smoking condition. This suggests the possibility that cigarette smoking in the unpleasant state may facilitate a decrease in the arousal level faster than with non-smoking. In both Experiments 1 and 2, the subjective rating results also suggested that cigarette smoking decreased anxiety. Taken together, both the physiological (LPP) and the psychological responses from our study suggest that cigarette smoking perhaps relieves stress.

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1. Introduction

Previous studies have suggested that people smoke cigarettes in order to regulate emotion and relieve negative emotions (for review, Kassel et al., 2003). For example, according to a survey study of adolescent smokers (Dozois et al., 1995; Nichter et al., 1997), the most frequently mentioned reasons for cigarette smoking were stress reduction and relaxation. Also, stress from life events is thought to be one of the important factors of smoking motivation (Warburton et al., 1991), and one laboratory experiment reported that stress decreases the ability to resist smoking (McKee et al., 2011). Moreover, smokers have higher neuroticism and anxiety traits than non-smokers (McCrae et al., 1978). This relationship between smoking behavior and personality traits (McCrae et al., 1978) suggests the possibility that cigarette smoking might be able to reduce anxiety, although there is also a possibility that smoking behavior might increase neuroticism and anxiety.

To address whether cigarette smoking actually has an effect of reducing stress and negative emotions, previous studies have examined the effect of smoking by using both psychological and physiological indices. In the results of subjective ratings, participants reported that acute smoking decreased their anxiety and stress (Nesbitt, 1973; Pomerleau and Pomerleau, 1987; Perkins et al., 1992; Parrott, 1995), which is in line with the expectation of smokers that cigarette smoking relieves stress. On the other hand, physiological results have indicated that smoking increases the heart rate (Pomerleau and Pomerleau, 1987; Perkins et al., 1992; Woodson et al., 1986), which is a sign of increased arousal. Arousal is an important component of the stress response (Winsky-Sommerer et al., 2005) and an increased arousal level is a typical physiological response elicited by a stressor (Chrousos, 1998). In addition, previous research on therapy has related low arousal levels with low stress levels, or with the relaxation effects of therapy (for example, music therapy, reviewed in Pelletier, 2004; mindfulness therapy, Mendelson et al., 2010). Therefore, there seems to be a close relationship between arousal and stress, although this relationship is not always supported (Bennett et al., 2003). Given this close relationship between arousal and stress, surprisingly, cigarette smoking and stress share a common physiological response (Kassel et al., 2003), indicating that the physiological responses to cigarette smoking are opposite to

Abbreviations: LPP, late positive potential; ERP, event-related potential; EEG, electroencephalogram; POMS, Profile of Mood States; EOG, electrooculography; ANOVA, analysis of variance.

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smokers' expectations that cigarette smoking reduces stress. This incongruity between the psychological and physiological responses to smoking is a phenomenon known as "Nesbitt's paradox", in which cigarette smoking relieves smokers psychologically; however, it increases the arousal level physiologically (Nesbitt, 1973). Thus, it is difficult to conclude whether cigarette smoking can actually reduce stress and negative emotions. To address this issue, it may be useful to measure other physiological indices, since Kassel et al. (2003) have pointed out that previous studies investigating the effect of cigarette smoking on stress reduction have mainly focused on peripheral processes such as the heart rate, as mentioned above (Pomerleau and Pomerleau, 1987; Perkins et al., 1992; Woodson et al., 1986).

In this context, our study focused on the late positive potential (LPP) component of the event-related potential (ERP), in order to test the effect of cigarette smoking on stress reduction. The ERP is one of the electrophysiological indices of brain activity and is derived from an electroencephalogram (EEG) time-locked to a specific event (for example, the presentation of a picture or a sound). The LPP is a component of the ERP and is a sustained positive polarity shown approximately 200 ms after stimuli (picture or sound) onset (reviewed in Hajcak et al., 2010; Hajcak et al., 2012; Olofsson et al., 2008). Many previous studies have reported that the LPP amplitude is greater in response to pleasant and unpleasant stimuli than to emotionally neutral stimuli (for example, Cuthbert et al., 2000; Schupp et al., 2000; Weinberg et al., 2012). Moreover, there is a positive relationship between the subjective arousal of stimuli and the LPP amplitude (Cuthbert et al., 2000). Taken together, the LPP indexes the level of arousal induced by emotional stimuli (reviewed in Hajcak et al., 2010; Hajcak et al., 2012; Olofsson et al., 2008). As mentioned above, an increased arousal level is related to stress (Chrousos, 1998). Thus, the LPP amplitude might be a useful index of the increase or decrease of stress, especially in cases where the arousal level is increased by emotionally unpleasant stimuli.

Using this characteristic of the LPP, we conducted 2 experiments with smokers. In order to collect baseline data, in Experiment 1 we assessed how cigarette smoking in an emotionally neutral state changes the LPP amplitude. To do so, we analyzed the ERP elicited when participants watched emotionally neutral images before and after cigarette smoking, or while just resting. In Experiment 2, we assessed how smoking a cigarette in a stressful state changes the LPP amplitude. To do so, we recorded the ERP while the participants watched emotionally unpleasant images. After that, participants smoked cigarettes (or just rested without cigarette smoking), and the ERP was then measured while participants watched emotionally neutral images. We hypothesized that if cigarette smoking actually reduces the arousal level, the LPP amplitude elicited by the unpleasant images would be decreased more by cigarette smoking than by resting.

In addition to the ERP, we measured the participants' subjective state before and after cigarette smoking (or resting) by using the Profile of Mood States (POMS) (McNair et al., 1971). The POMS assesses mood states mainly related to anxiety along 6 dimensions (for details, please refer to the Methods section) and has been used in previous studies on the effect of cigarette smoking on stress (for example, Pomerleau and Pomerleau, 1987). We hypothesized that the participants would report less anxiety after cigarette smoking than after resting. By measuring both physiological (LPP) and psychological (POMS) responses, we expected that our study would offer helpful data to examine whether cigarette smoking actually has the effect of reducing stress.

2. Methods

2.1. Participants

Fourteen young, male, Japanese smokers (right-handed undergraduate or graduate students; age range 21–25 years) participated in the 2 experiments. The participants were the same in both Experiments 1 and 2. Thirteen participants were included in the final analysis, since

the quality of one participant's EEG was poor. They all reported smoking at least one or more cigarettes per day. We focused only on smokers, since smokers and non-smokers are fundamentally different in terms of baseline levels of stress (Gilbert and Gilbert, 1995). Written informed consent was obtained from all participants prior to the start of the study. All study protocols were approved by the ethics committee in the Faculty of Design at Kyushu University, Japan.

2.2. Stimuli

A total of 60 images (40 neutral and 20 unpleasant images) were selected from the International Affective Picture System (IAPS) (Lang et al., 2008). The neutral images included images of shoes, a cup, and a tissue box, while the unpleasant pictures included images of a dirty toilet, a cockroach, and an injured animal. The mean IAPS normative valence ratings (Lang et al., 2008) of the images selected in the present study were 5.0 for neutral images and 2.9 for unpleasant images (10 = very pleasant; 0 = very unpleasant).

The picture identification numbers from IAPS were as follows: Before the break (Experiment 1): 5471, 6150, 7001, 7003, 7010, 7017, 7020, 7035, 7037, 7041, 7050, 7059, 7090, 7150, 7161, 7175, 7185, 7211, 7255, and 7705; Before the break (Experiment 2): 1205, 1220, 1270, 1271, 3010, 6020, 7078, 9090, 9110, 9183, 9290, 9295, 9300, 9301, 9320, 9325, 9395, 9405, 9571, and 9590; After the break (Experiment 1 and Experiment 2): 5510, 7000, 7002, 7004, 7009, 7012, 7019, 7032, 7036, 7038, 7045, 7055, 7077, 7130, 7160, 7170, 7207, 7233, 7491, and 7950.

2.3. Procedures

The participants arrived 3 h before the experiment and rested (for example, read a book) without cigarette smoking during this time. After that, they moved to the testing room and sat on chairs which were placed approximately 80 cm from a monitor (17-inch monitor, 1024 × 768 resolution). EEG and electrooculography (EOG) sensors were attached to the participants' scalps.

Fig. 1 shows the procedures for Experiment 1 and Experiment 2. In Experiment 1 (Fig. 1A), 20 neutral images were presented for 3 min, after which the participants assessed their subjective ratings. The participants then took a 3-minute break, in which they smoked a cigarette (smoking condition) or simply rested without smoking a cigarette (non-smoking condition). The cigarettes were the individual participant's personal usual brand. After the break, 20 neutral images (different from the images presented before the break) were presented

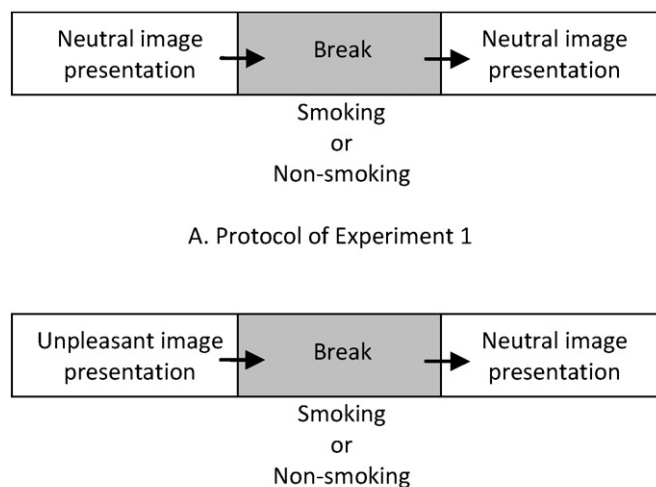


Fig. 1. Procedures of Experiment 1 (A) and Experiment 2 (B).

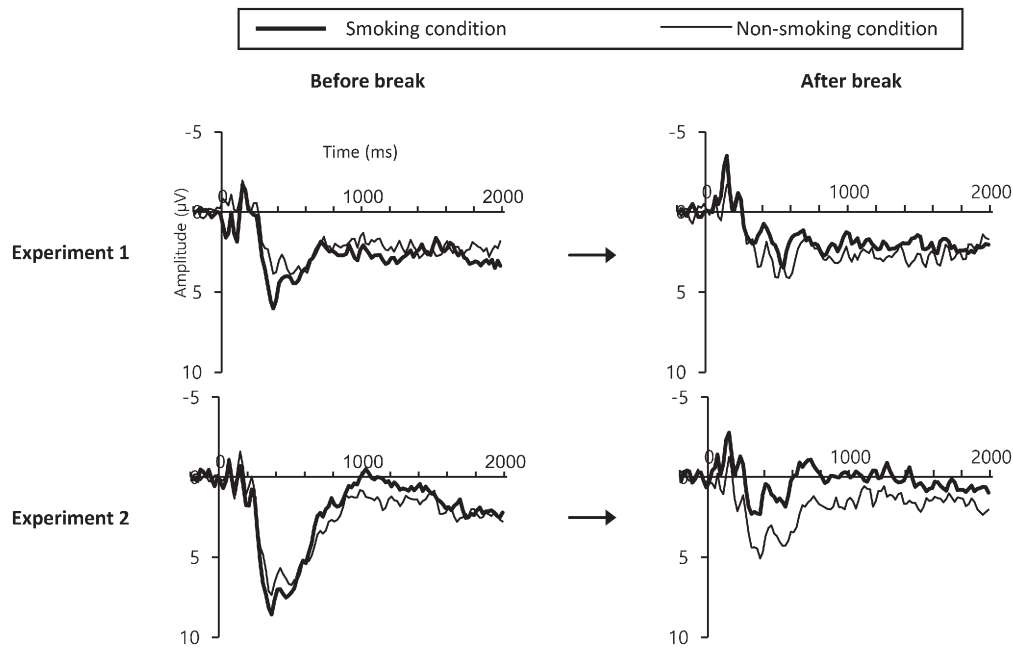


Fig. 2. Grand-averaged event-related potential (ERP) waveforms (Pz site) in smoking condition (thick line) and non-smoking condition (thin line). The first and second rows show ERP waveforms from Experiment 1 and Experiment 2, respectively. The left and right columns indicate before and after the break, respectively.

for 3 min, and the participants again assessed their subjective ratings. The smoking and non-smoking conditions were conducted on different days, and the order of the conditions was counterbalanced.

The procedure for Experiment 2 (Fig. 1B) was the same as that for Experiment 1, except that the unpleasant images were presented before the break for 3 min as stress stimuli. The same neutral images were presented after the break in both experiments. Experiment 2 was conducted approximately 3 months after Experiment 1. The participants' brands of cigarettes were the same in both experiments.

The protocol for the image presentation was the same before and after the break in both Experiments 1 and 2. The 20 IAPS images were presented twice, and yellow circles were presented 10 times (a total of 50 trials). The yellow circles were presented to sustain attention, and the participants were asked to press a button with their right hand as quickly as possible in response to the circles. In each trial, a cross shape was presented (500 ms), followed by an IAPS image or a yellow circle (2000 ms). The interstimulus interval time was 1000 ms. On our analysis, we focused only on responses to the IAPS images.

For the subjective ratings, the participants completed the brief Japanese version (Yokoyama, 2005) of the POMS (McNair et al., 1971) with 6 subscales: tension–anxiety, depression, anger–hostility, vigor, fatigue, and confusion. The ratings included 30 adjectives (for example, anxious, angry, active, and sad), and the participants were asked to evaluate their moods on a 5-point scale, ranging from 0 (“not at all”) to 4 (“quite frequently”).

2.4. ERP measurements and analysis

While the participants watched the images, EEG signals were recorded at the Fz (medial frontal), Cz (medial central), and Pz (medial parietal) sites, based on the International 10–20 System (Towle et al., 1993), using a Polymate AP1532 system (TEAC, Tokyo, Japan). The electrodes were referenced to averaged ears, and a ground electrode was attached to the middle of the forehead. EOG was recorded to detect blinking, with electrodes placed above and below the right eye. All electrode impedances were below 10 k Ω .

The EEG signals were digitized at a sampling rate of 500 Hz and were amplified (band pass, 0.1–40 Hz) using the EMSE Suite (Source Signal Imaging, San Diego, CA). We excluded trials containing

artifacts > 50 μ V. The target stimulus presentation of –200 to 2000 ms was averaged for each Session (before and after the break) in each Condition. Prior to averaging, individual trial waveforms were baseline corrected (–200 to 0 ms). The mean number of trials was 27.4 (standard deviation (SD) = 8.1). Following the stimulus onset, the LPP was scored as the averaged activity in 4 time windows: 200–400 ms, 400–600 ms, 600–1000 ms, and 1000–2000 ms. We focused on the LPP at the Pz site, since it has been reported to be maximal at this site (for example, Cuthbert et al., 2000).

2.5. Statistical analysis

For the LPP, we conducted a repeated measures analysis of variance (ANOVA) with *Time Window* (200–400 ms, 400–600 ms, 600–1000 ms, and 1000–2000 ms), *Condition* (smoking versus non-smoking), and *Session* (before versus after the break) as within-subject factors. The Greenhouse–Geisser correction was applied where sphericity was violated. For the POMS scores, we conducted a repeated measures ANOVA, with *Condition* and *Session* as within-subject factors. When an interaction was significant, pairwise comparisons were performed with the Bonferroni correction. Statistical significance was accepted at the 5% level ($p < 0.05$) (SPSS, Chicago, IL, USA).

3. Results

3.1. LPP

Fig. 2 illustrates the grand-averaged ERP waveforms elicited at the Pz site. The differences in the waveforms between the smoking and non-smoking conditions are relatively clearer after rather than before the break. Table 1 summarizes the statistical results of the LPP responses.

In Experiment 1, there was reliable interaction of *Time Window* and *Session* (Table 1). Pairwise comparisons between Sessions within each *Time Window* (critical p value = 0.0125 for 4 comparisons) did not reveal significant difference (200–400 ms, $p = 0.046$; 400–600 ms, $p = 0.028$; 600–1000 ms, $p = 0.687$; 1000–2000 ms, $p = 0.704$). The interaction of *Condition* and *Session* was also reliable (Table 1). As shown in Fig. 3A, pairwise comparisons between Sessions within each *Condition* (critical p value = 0.025 for 2 comparisons) revealed that the LPP

significantly decreased from before to after the break ($p = 0.015$) in the smoking condition, but not in the non-smoking condition ($p = 0.815$).

In Experiment 2, there were main effects of *Time Window* and *Session*, and reliable interaction of *Time Window* and *Session* (Table 1). Pairwise comparisons between *Sessions* within each *Time Window* (critical p value = 0.0125 for 4 comparisons) revealed that the LPP significantly decreased from before to after the break in time windows 200–400 ms ($p = 0.003$) and 400–600 ms ($p = 0.000$), but not in time windows 600–1000 ms ($p = 0.135$) and 1000–2000 ms ($p = 0.445$). Unlike Experiment 1, there was no reliable interaction of *Condition* and *Session* in Experiment 2 (Table 1). However, for comparison between Experiments 1 and 2, we conducted pairwise comparisons between *Sessions* within each *Condition* (critical p value = 0.025 for 2 comparisons). As shown in Fig. 3B, these revealed that the LPP significantly decreased from before to after the break in both the smoking condition ($p = 0.001$) and the non-smoking condition ($p = 0.012$). In Experiment 2, there was also reliable interaction of *Time Window*, *Condition*, and *Session* (Table 1). As shown in Fig. 4A, pairwise comparisons among *Sessions* within each *Condition* in each *Time Window* (critical p value = 0.00625 for 8 comparisons) revealed that the LPP significantly decreased from before to after the break for time window 200–400 ms ($p = 0.002$) in the smoking condition, but not in the non-smoking condition ($p = 0.090$). However, for the time window 400–600 ms (Fig. 4B), the LPP significantly decreased from before to after the break in both the smoking and the non-smoking conditions (all $p < 0.001$). For time windows 600–1000 ms and 1000–2000 ms, the LPP did not significantly change from before to after the break in the smoking or the non-smoking conditions (all $p \geq 0.05$).

3.2. POMS

Table 2 shows the ratings for each subscale of the POMS in Experiment 1 and Experiment 2. In Experiment 1, the tension–anxiety subscale showed a significant main effect of *Session* ($F(1,12) = 10.400$, $p = 0.007$) and a reliable interaction ($F(1,12) = 6.353$, $p = 0.027$). Pairwise comparisons between *Sessions* within each *Condition* (critical p value = 0.025 for 2 comparisons) indicated that subjective tension–anxiety decreased from before to after the break in the smoking condition ($p = 0.003$), but not in the non-smoking condition ($p = 0.544$).

In Experiment 2, the tension–anxiety, depression, and anger–hostility POMS subscales showed a significant main effect of *Session* (tension–anxiety: $F(1,12) = 5.149$, $p = 0.043$; depression: $F(1,12) = 9.432$, $p = 0.010$; anger–hostility: $F(1,12) = 5.571$, $p = 0.036$), indicating that the subjective ratings had decreased from before to after the break. However, no subscale showed any significant interaction or main effect of *Condition* ($p > 0.05$).

4. Discussion

Previous studies on the effect of cigarette smoking on stress reduction have reported a disparity between the subjective ratings and the

physiological responses. In order to compensate for the weak points in these studies, our study adapted the LPP as the physiological index and examined how cigarette smoking changes the LPP amplitude. The subjective ratings (POMS) were also measured before and after cigarette smoking.

4.1. LPP

Before discussing the effect of cigarette smoking in the unpleasant state on the LPP (Experiment 2), the effect of cigarette smoking in the emotionally neutral state in Experiment 1, in order to establish baseline data, should be discussed. In Experiment 1, we found different patterns of change of the LPP between after smoking and non-smoking; the LPP was decreased by smoking, but not by non-smoking. Given that the LPP amplitude reflects the arousal level (Cuthbert et al., 2000; Schupp et al., 2000; Weinberg et al., 2012), the results suggest that cigarette smoking in the emotionally neutral state decreases the arousal level, while non-smoking does not. Since emotionally neutral images were presented before and after the break in Experiment 1, it would be difficult to interpret this result as an effect of smoking on stress reduction. However, it might be suggested that cigarette smoking in the neutral state reduces the arousal level and thus results in relaxation.

In Experiment 2, unpleasant images were presented before the break, and emotionally neutral images were presented after the break. Since many previous ERP studies have reported that the LPP is greater in response to emotional (pleasant and unpleasant) stimuli than to emotionally neutral stimuli (for example, Cuthbert et al., 2000; Schupp et al., 2000; Weinberg et al., 2012), it was expected that the LPP amplitude would decrease after the break. The results showed that the LPP amplitude for the time window 400–600 ms was decreased both by smoking and non-smoking; however, the LPP amplitude for the time window 200–400 ms was decreased only by cigarette smoking. A possible interpretation for this result is that the high arousal level evoked by watching unpleasant images decreased at a faster rate in the smoking condition than in the non-smoking condition. Thus, cigarette smoking in the unpleasant state might facilitate decreased stress levels more than in the resting (non-smoking) state, given that there is a close relationship between arousal level and stress (Chrousos, 1998; Winsky-Sommerer et al., 2005). Thus, the Experiment 2 results suggest that cigarette smoking is more effective in relieving stress than resting without smoking.

In Experiment 2, the LPP amplitude for the time windows 600–1000 ms and 1000–2000 ms was not affected by *Condition* or *Session*. According to previous studies (Weinberg and Hajcak, 2011; Weinberg et al., 2012), the earlier part of the LPP reflects capture of attention in a relatively obligatory manner, whereas the later part reflects relatively sustained attention and elaborate processing of stimuli. This suggests that cigarette smoking affects the earlier attention process, but not the later sustained process. Future ERP studies are needed to confirm this issue.

There are some differences between the present study and the previous studies that assessed changes in the ERP responses to cigarette smoking (for example, Domino, 2003; Houlihan et al., 1996; Ilan and Polich, 2001). For example, in an ERP study by Houlihan et al. (1996), the P300 was measured while participants completed a visual oddball task, both before and after cigarette smoking. The oddball task indicates a paradigm in which 2 or 3 types are presented in different probability, and the individual has to press a button as soon as possible in response to a stimulus with a low presentation probability (i.e., the target stimulus). In the study by Houlihan et al. (1996), the target stimulus was the letter “X” and the non-target stimulus was the letter “O”; the results indicated that the P300 latency to the target stimulus decreased after cigarette smoking. This suggests that cigarette smoking improved cognitive performance, in accordance with other ERP studies on cigarette smoking (Pritchard et al., 2004), given that the P300 latency evoked by the oddball task usually reflects the degree of difficulty of

Table 1
Analysis of variance (ANOVA) effects of ERP responses.
Significant p -values are in bold.

Factor	$df(h,e)$	Experiment 1		Experiment 2	
		F	P	F	P
Time window	3, 36	2.041	0.167	13.598	0.001
Condition	1, 12	0.001	0.973	0.846	0.376
Session	1, 12	3.437	0.088	18.643	0.001
Time window \times Condition	3, 36	0.876	0.463	0.597	0.621
Time window \times Session	3, 36	3.878	0.017	16.693	0.000
Condition \times Session	1, 12	8.329	0.014	2.592	0.133
Time window \times Condition \times Session	3, 36	0.711	0.552	5.590	0.019

Note. $df(h,e)$: degrees of freedom. The Greenhouse–Geisser correction was applied where sphericity was violated; the uncorrected degrees of freedom are reported in this table.

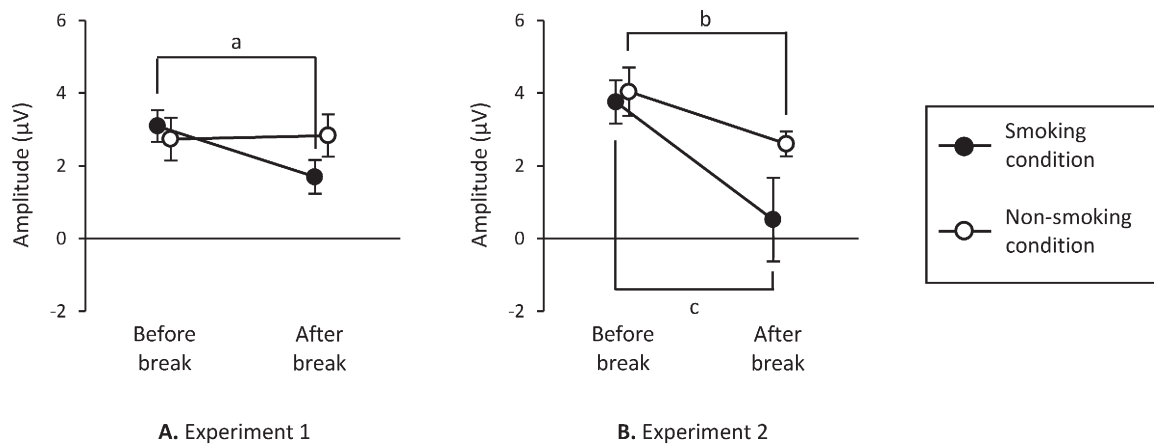


Fig. 3. The late positive potential (LPP) in Experiment 1 (A) and Experiment 2 (B). Amplitude of the LPP was averaged across all time windows. Mean and standard errors: a, $p = 0.015$; b, $p = 0.012$; c, $p = 0.001$ (pairwise comparisons between before and after the break in each Condition; Bonferroni-corrected critical p -value: 0.025).

the task. In the present study, we also conducted the oddball task; however, we analyzed only responses to non-target stimuli (i.e., neutral or unpleasant images), not responses to target stimuli (i.e., a yellow circle). This was because we focused on changes in the emotional state between before and after smoking, rather than changes in cognitive performance. The images that were presented as non-target stimuli in the present study were more related to emotion (pleasant versus unpleasant; relaxed versus aroused) than the letters presented in the previous study (i.e., “O” and “X”) (Houlihan et al., 1996). To the best of our knowledge, there has been no ERP study that has tested the effect of cigarette smoking on emotion evoked by watching images. Thus, we expect that the present study expands the availability of ERP in studies on effects of cigarette smoking not only as an index of cognitive performance, but also as an index of emotion and stress.

4.2. Subjective ratings

In addition to the LPP, we measured the participants' mood state by using the POMS. In Experiment 1, the results revealed that the subjective tension and anxiety levels decreased by smoking, but not by non-smoking. This supports the results of the previous studies, which reported that smoking decreases subjective anxiety and stress (Nesbitt, 1973; Pomerleau and Pomerleau, 1987; Perkins et al., 1992). More importantly, this is compatible with the results of the LPP shown in Experiment 1, which suggested that the physiological arousal level decreased only by smoking, not by non-smoking. As mentioned in the Introduction, the

previous studies have reported on Nesbitt's paradox issue; although participants reported that cigarette smoking made them feel less anxious and stressed (Nesbitt, 1973; Pomerleau and Pomerleau, 1987; Perkins et al., 1992), the results of peripheral processes, such as the heart rate, indicated that cigarette smoking and stress have common physiological responses (Pomerleau and Pomerleau, 1987; Perkins et al., 1992; Woodson et al., 1986). The subjective ratings (POMS) and physiological responses (LPP) from our study indicate the same results, which again sheds light on the Nesbitt's paradox issue.

However, in Experiment 2, we could not find a different pattern in changes of the subjective ratings between the smoking and non-smoking conditions; tension–anxiety, depression, and anger–hostility were all decreased by both smoking and non-smoking. This is a somewhat different result from the LPP results, which suggested that cigarette smoking in the unpleasant state might facilitate decreased stress levels more than non-smoking. One possible reason for this incongruity between the subjective ratings and the LPP responses might be that the ERP is able to reflect very early and subtle changes in arousal between smoking and resting, while the self-report is not. Indeed, the difference in the LPP between smoking and non-smoking was shown in very short time windows (i.e., 200–400 ms). Another possible reason for the disparity between the subjective ratings and the LPP response in Experiment 2 might be that the images presented as stress stimuli were too unpleasant, and thus almost the same level of decrease of subjective anxiety between smoking and non-smoking might have resulted. Future studies that apply other stress stimuli (i.e., less unpleasant images

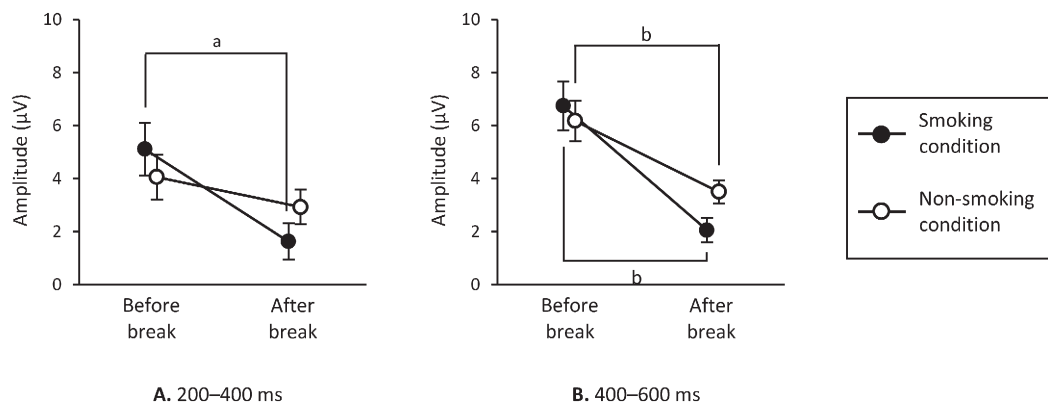


Fig. 4. The late positive potential (LPP) for time windows 200–400 ms (A) and 400–600 ms (B) in Experiment 2. Mean and standard errors: a, $p = 0.002$; b, $p < 0.001$ (pairwise comparisons between before and after the break in each Condition; Bonferroni-corrected critical p -value: 0.006).

Table 2

Ratings of the Profile of Mood States (POMS).
Mean and standard errors.

		Smoking condition		Non-smoking condition	
		Before break	After break	Before break	After break
Experiment 1	Tension–anxiety	3.8 (0.8)	1.3 (0.5)	2.5 (0.7)	2.8 (0.9)
	Depression	0.5 (0.2)	0.2 (0.2)	1.2 (0.5)	1.2 (0.6)
	Anger–hostility	0.3 (0.2)	0.2 (0.1)	0.7 (0.4)	1.2 (0.7)
	Vigor	1.5 (0.5)	1.4 (0.5)	0.9 (0.4)	0.5 (0.3)
	Fatigue	3.3 (1.1)	2.3 (0.7)	3.6 (1.0)	3.8 (1.1)
Experiment 2	Confusion	1.8 (0.5)	1.6 (0.4)	1.5 (0.4)	1.7 (0.6)
	Tension–anxiety	2.6 (0.7)	1.7 (0.7)	2.8 (0.9)	1.2 (0.7)
	Depression	1.8 (0.6)	0.5 (0.4)	1.9 (0.7)	0.9 (0.5)
	Anger–hostility	1.2 (0.6)	0.6 (0.4)	0.8 (0.4)	0.3 (0.3)
	Vigor	1.5 (0.5)	1.1 (0.5)	0.9 (0.3)	1.5 (0.6)
	Fatigue	3.4 (0.8)	3.0 (0.7)	4.0 (1.1)	4.4 (1.6)
	Confusion	1.4 (0.3)	1.2 (0.5)	1.1 (0.3)	1.1 (0.4)

than those presented in Experiment 2) are needed to address this question.

4.3. Limitations and future directions

Several limitations must be considered when interpreting the results of the current study. First, it is not possible to conclude whether smoking generally has an effect to reduce stress levels, since our participants included only smokers, not non-smokers. Previous findings have suggested that smokers have higher baseline stress levels than non-smokers. For example, in the study by Parrott (1995), smokers reported lower stress levels after smoking than before smoking (baseline), while nonsmokers reported similar baseline stress levels to the stress levels reported by smokers after smoking. Additionally, as mentioned in the Introduction, smokers have higher neuroticism and anxiety traits than non-smokers (McCrae et al., 1978), suggesting that smokers also have higher baseline arousal levels than nonsmokers. Thus, the reason why smoking reduces the arousal level and perhaps the stress level in smokers might be simply because smoking reduces the stress levels of smokers to the same level as that of non-smokers, and not because smoking generally has an effect on stress levels. Future studies are required using the same protocol as the present study for both smokers and non-smokers, in order to examine whether smoking generally has an effect to reduce stress levels.

Second, all of the participants were males. Since there are reported gender differences in smoking behavior (Bauer et al., 2007; File et al., 2001; Perkins et al., 1992), it is difficult to predict whether female smokers would show the same results. Thus, future studies need to be done with female smokers, using the same experiment protocol as the present study.

Third, in our study, the participants rested without doing anything as a control condition. Previous studies investigating the effect of smoking have adapted both a pre/post smoking versus pre/post resting design (Hasenfratz et al., 1989; Michel et al., 1987) and a pre/post smoking versus pre/post sham smoking design (Cook et al., 1996). However, some authors (for example, Pritchard et al., 2004) have argued that merely resting is not thought to have the same sensory or motor components as smoking. Thus, future studies would need to use identical-appearing denicotinized cigarettes or gum in the non-smoking condition.

Finally, we did not measure heart rates; it was therefore impossible to compare changes in peripheral responses between the current study and the previous studies. Future studies would need to measure brain activity and heart rate simultaneously, in order to obtain rich physiological data to resolve Nesbitt's paradox.

5. Conclusion

The aim of our study was to investigate whether cigarette smoking relieves stress and reduces unpleasant emotions by using the LPP, a component of the ERP, which reflects the arousal level. In Experiment 1, the LPP in the emotionally neutral state decreased only by smoking, suggesting that cigarette smoking in the neutral state reduced the arousal level. In Experiment 2, smoking in the unpleasant state decreased the LPP at a faster rate (time window 200–400 ms) than non-smoking, suggesting that cigarette smoking in the unpleasant state facilitates a decrease in the arousal level. Taken together, the results of the LPP shown in the present study indicate that cigarette smoking might decrease the arousal level and perhaps relieve stress for smokers.

Acknowledgments

The authors sincerely thank Mutsuhiro Fujiwara for his technical assistance with this study. We also thank the participants of the study. This research was supported by grants from Kyushu University (grant number: LAKF 620212).

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